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Bioactive ceramics

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INTRODUCTION INTO THE FIELD OF BIOMATERIALS

Materials science can be defined as the science in which are studied the relations between the chemical composition, the structure and the properties of materials. Materials technology can be defined as the technology to prepare and to mold materials into commodities suitable for application. In the case of biometarials this application lies in the field or surgery or dentistry. The surgeon and the dentist must choose a material, they must in many cases either mold this material or adjust its form or that of the receiving tissue. And after surgery or implantation they must evaluate the performance of the dental or medical device.

On one side biomaterials science in limited in its possibilities by the limited availability of synthetic materials which must replace and simulate the original tissues. Therefore, the biomaterials scientist needs sufficient biological training and especially must know sufficiently about the materials properties to be able to design his biomaterials in the right direction.

On the side of biomaterials applications the surgeon and the dentist are limited in the choice of biomaterials and in their molding as many materials contain toxic components, or may cause allergy or simply may evoke foreign body reactions from the surrounding tissues. Therefore, the surgeon and the dentist need general medical training.

A big difference between the indutrial aplplication of materials and the applications of biomaterials is that in the latter case mostly an individual design and molding is necessary. Therefore, one of the prerequisites necessary in any surgical or detal technique is that either molding of the biomaterial must be made simple and safe of adaptation of the form of the receiving tissue or organ must be made simple and safe. Many materials scientists working in the field of biomaterials science do not realize how important this aspect is in the practice of biomaterials application. This is the main reason why so many initiatives in this field do not end in a successful application in surgery or dentistry.

Nevertheless, at the moment there are many possible applications which have been realized or which will be realized very soon. The number of applications is not simply increasing. Also the quality nd the performance of biomaterials and the medical devices in terms of service life increase steadily. That is due to the combined and continuous efforts of materials scientists, biologists, histologists, technologists, surgeons, dentists, toxicologists, etc. in this interesting multidisciplinary field. Every success in this field as in any other field of technology or medicine is the result of much work and is, as my friend the philosophe has said, a victory over nature by obedience to the laws of nature.

From biomaterials in geneal to bioactive ceramics

The bioceramics all belong to the group of biomaterials replacing bone and, hence, they are of special importance to orthopaedics and dentistry.

The first more or less successful orthopaedic techniques were using so-called 'sufficiently compatible materials'. By definition these types of materials release ions or other contituents which influence the surrounding tissue in an unfavorable, but still tolerable way. The most well known example is that of stainless steel hip implants fixed in the femur with polymethilmetacrylate bone cement. The stainless steel releases toxic metal ions but slowly, whereas the PMMA bone cement releases monomer and toxic activator components. As a result, the femoral bone encapsulates the implant with fibrous tissue which can be seen as a foreign body reaction. A further disadvantadge of the bone cement is its development of heat during the setting. The temperature rises so much that the monomer starts to boil in the setting cement. It is true that by this boiling the cement expands a little bit so that a good initial fixation is achieved. However the excessive heat can cause bone necrosis close to the implant and so may lead to rejection by the body.

That was the state of the art around 1960. After that stage compatible biomaterials have been developed. By definition these are materials which may release ions or other constituents but they do not influence the surrouding tissues unfavorably. Typical examples are hip implants made out of CoCrMo alloys or acetabula made out of ultrahigh molecular weight polyethylene. In order to avoid complications like those with PMMA bone cements many surgeons operate nowadays with more careful reaming of the bone tissue and with fixation of the implants by press-fit. However, in about 10 to 20% of the cases this still leads to postoperative complications like foreign body reactions.

During the same period around 1970 so-called 'bioinert' materials were developed and now we come to the bioceramics. By definition these materials give no detectable release of ions or any other constituents. The best example of this group of materials is high purity and high density alumina. Other developments are different forms of zirconia and of amorphous carbon. It has been shown that it is difficult to adjust the form of the receiving bone to such prefabricated implants. Moreover such implants still lead to a foreign-body reaction due to their encapsulation into fibrous tissue. Therefore, this has inhibited the large-scale application of these materials in orthopaedic surgery, although several manufactures have brought them om the market.

Since about 1972 several scientists have developed so-called bioactive ceramics. Upon implantation these ceramics lead to direct growth of bone tissue onto the implant without an intermediary layer of fibrous tissue. Examples of such materials are bioglasses which can contain calcium, phosphate and silicate, and also ceramics like sintered hydroxyapatite or tricalcium phosphate. Thereby, these bioceramics might be surface active (bioglasses), resorbable (tricalcium phosphate) or hardly resorbable (hydroxyapatite). Their most important property is that they are osteoconductive, which means that they promote direct ongrowth of bone and so do not lead to any foreign body reaction. This means that it is practically impossible to retrieve such implants. Their ingrowth in the bone is irreversible.

FUTURE DEVELOPMENTS

The disadvantadge of bioactive ceramics is that they must be premolded before insertion of the implant. Therefore, several scientists try to develop calcium phosphate cements which have the same biological properties as bioactive ceramics, but which can be molded by the surgeon or the dentist during the operation. We are involved in such a project at the moment with Prof. Dr. J.A. Planell at Universidad Politécnica de Cataluña in Barcelona in which we will develop several formulas, both resorbable and non resorbable.